TR-961

PULSED GAMMA INITIATION OF BREAKDOWN IN GAS TUBES

Alan J. Talbert

Neil D. Wilkin

258 200

10 July 1961

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ORDNANCE CORPS ● DEPARTMENT OF THE ARMY
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DA 507-06-011
OMS 5530.12.512N
DOFL Proj 54050 10 July 1961

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Neil D. Wilkin

FOR THE COMMANDER:
Approved by

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R. D. Hatcher
Chief, Laboratory 500

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ABSTRACT

Miniature cold-cathode diodes of the GE XD series were subjected to pulses of gamma radiation from the electron linear-acceleration (linac) facility at General Atomic at LaJolla, California, to determine under laboratory conditions the values of gamma dose and dose rate required to initiate breakdown in the diodes at different bias voltages. Elapsed time between gamma pulse onset and diode breakdown was measured. Curves are presented of the relationship between gamma dose and diode breakdown as a function of diode voltage. The data are compared with similar data taken in Operation Plumbbob (Nevada 1957). The results show that each of the diodes tested is applicable to nuclear-proofing devices with corresponding operating voltage range.

1. INTRODUCTION

The purpose of these tests was to extend the knowledge of the operation of gamma-initiated nuclear-proofing switches by means of gamma pulses comparable with those produced by atomic explosions. Measurements were made to determine the values of gamma dose and dose rate required to initiate breakdown in gas diodes at different bias voltages. Time elapsed between gamma pulse onset and tube breakdown was measured for several GE XD type diodes (ref 1) and for a QF848 gas tetrode (ref 2). An attempt was made to measure gamma dose rate dependency of diode firing sensitivity. The diode breakdown characteristics are presented in the form of curves of diode bias versus gamma dose for diode breakdown. The following diodes were tested:

Diode	Nominal Firing Voltage (V_f)
XD-100	100 v
XD1C	113
XD-150	150
XD-225	225
XD-300	300
XD-375	375
XD-750	750

The data obtained, using gamma pulses provided by means of the electron linear accelerator (linac) at General Atomic, were intended for comparison with previous, less controlled data from Operation Plumbbob (Nevada, 1957). The linac at GA is capable of producing gamma pulses up to 20-Mev energy and up to 100 rads dose per pulse with pulse duration variable from 0.2 to 5 μsec. In dose, at least, this is in the range of magnitude required for simulation of the nuclear weapon gamma pulse over the range in which the diodes are fired by the gamma pulse. The linac is a valuable tool for testing gamma-sensitive elements for their nuclear vulnerability as well as for their applicability to nuclear proofing.

2. BACKGROUND

The development at DOFL of influence fuzes which appeared to be vulnerable to actuation or sterilization by nuclear radiation stimulated study of methods of sterilizing fuzes during the incidence of most of the effects of nearby nuclear explosions. One of these methods was a gamma-sensitive switch employing a GE XD1C or a Victoreen XD4C (ref 1, 3) cold-cathode gas diode in a circuit as shown in figure 1.

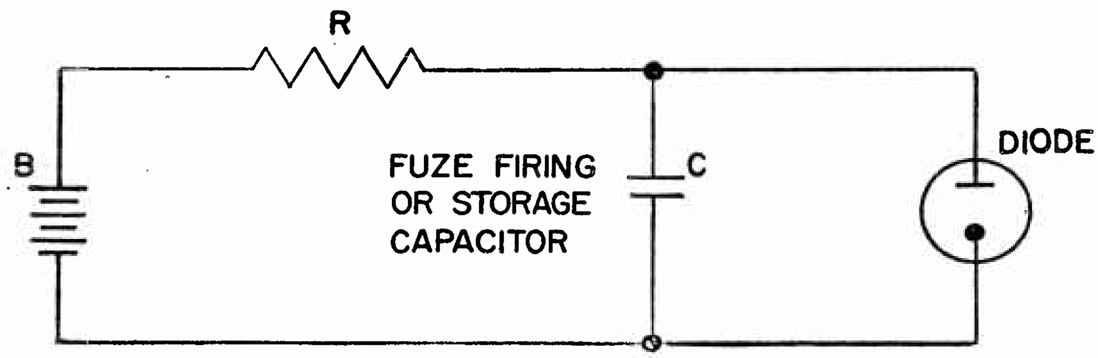

Figure 1. Basic diode nuclear proofing circuit.

Cold-cathode gas diodes were first tested in a nuclear weapon environment in the Operation Redwing (Pacific, 1956). Diodes were biased at a voltage below their normal breakdown voltage V_f. It was anticipated that, at a bias voltage less than V_f, breakdown in the diode would be initiated by sufficiently intense ionizing radiation (primarily gamma) from a nuclear explosion. A small number of GE-XD1C's and Victoreen-XD4C's were exposed to a nuclear explosion and it was found that some diodes did fire at certain ranges from the weapon. This experiment led to a more comprehensive test in Operation Plumbbob. Here a total of 33 XD1C's and 33 XD4C's were exposed in four atomic explosions, using bias ratio values of $V/V_f \cong 0.65, 0.80$, and 0.95. The results revealed that for the function outlined above, the XD1C's were markedly more sensitive to gamma initiation than the XD4C's. Approximate ranges (from the weapon) of operation for diodes biased at specified levels were determined. The XD1C's appeared promising as nuclear-proofing devices, but more data were needed to establish the limits (in terms of range from weapons) of their usefulness.

During the same test series in 1957, a number of influence type (contrasting with more-or-less conventional pressure-actuated type) mine fuzes were tested for detonation and sterilization by various effects produced by atomic explosions (ref 4). Some fuzes were found to be vulnerable to actuation by bomb effects within a certain range from the weapon. Fuzes that could be initiated in this fashion were in need of a device to temporarily sterilize the fuze during the period of the bomb's influence. Such a device would necessarily utilize for its actuation an early-arriving bomb effect which would not affect the fuze adversely otherwise and which would precede the disturbing influences. The early portion of the initial gamma spectrum fulfills these requirements. The early gamma pulse can be used to fire a cold-cathode gas diode which, in turn, will discharge a storage or firing capacitor, sterilizing the fuze for the charge time of the capacitor.

Since Operation Hardtack (Pacific 1958), the exposure of cold-cathode gas tubes (and other nuclear-proofing devices) in the field under actual operating conditions has been indefinitely suspended by the moratorium on nuclear weapons tests. The linac at General Atomic provides a method of producing high-energy gamma pulses for simulation of the proppt gamma pulse of nuclear explosions.

3. EXPERIMENTAL SETUP

To produce the gamma pulses used in these experiments, single electron pulses from the linac were projected through a lead target sufficiently thick (5/16 in.) to stop nearly all the electrons. The electron pulses of 7-Mev energy and about 4-μsec duration, produced bremsstrahlung gammas in the lead target, providing a gamma spectrum of about 3 Mev effective energy (ref 5). Relatively long pulse duration was used to vary gamma dose over a wide range by changing pulse height (electron beam current) only. Changing pulse duration required time-consuming retuning of the linac.

The experimental setup is shown in figure 2. Diodes were placed next to the lead target and centered in the gamma beam. Bias was applied to the diodes by a highly regulated and filtered d-c supply. (Output change, less than 0.02 v + 0.02 percent of output voltage for a 10-percent change in line voltage. Load regulation, 0.02 percent for 0 to 10 ma.) Diodes were biased at predetermined values below V_f, and breakdown was initiated by the increased ionization in the diode gas effected by an ensuing gamma pulse. The gamma dose and percent bias at which the diode fired constitute a threshold point. The change in diode voltage at breakdown was recorded by means of oscilloscope photographs. A record of the linac electron pulse was photographed simultaneously with the diode voltage pulse on a dual-beam scope, the beam pulse being used to trigger the sweep. The normal V_f of each diode was determined at intervals during each series of pulses in order to detect any variation in V_f as a result of previous diode breakdown.

4. PROCEDURE

Threshold points were determined as follows. Electron beam current was adjusted to the highest value obtainable at a pulse width of 4 μsec.

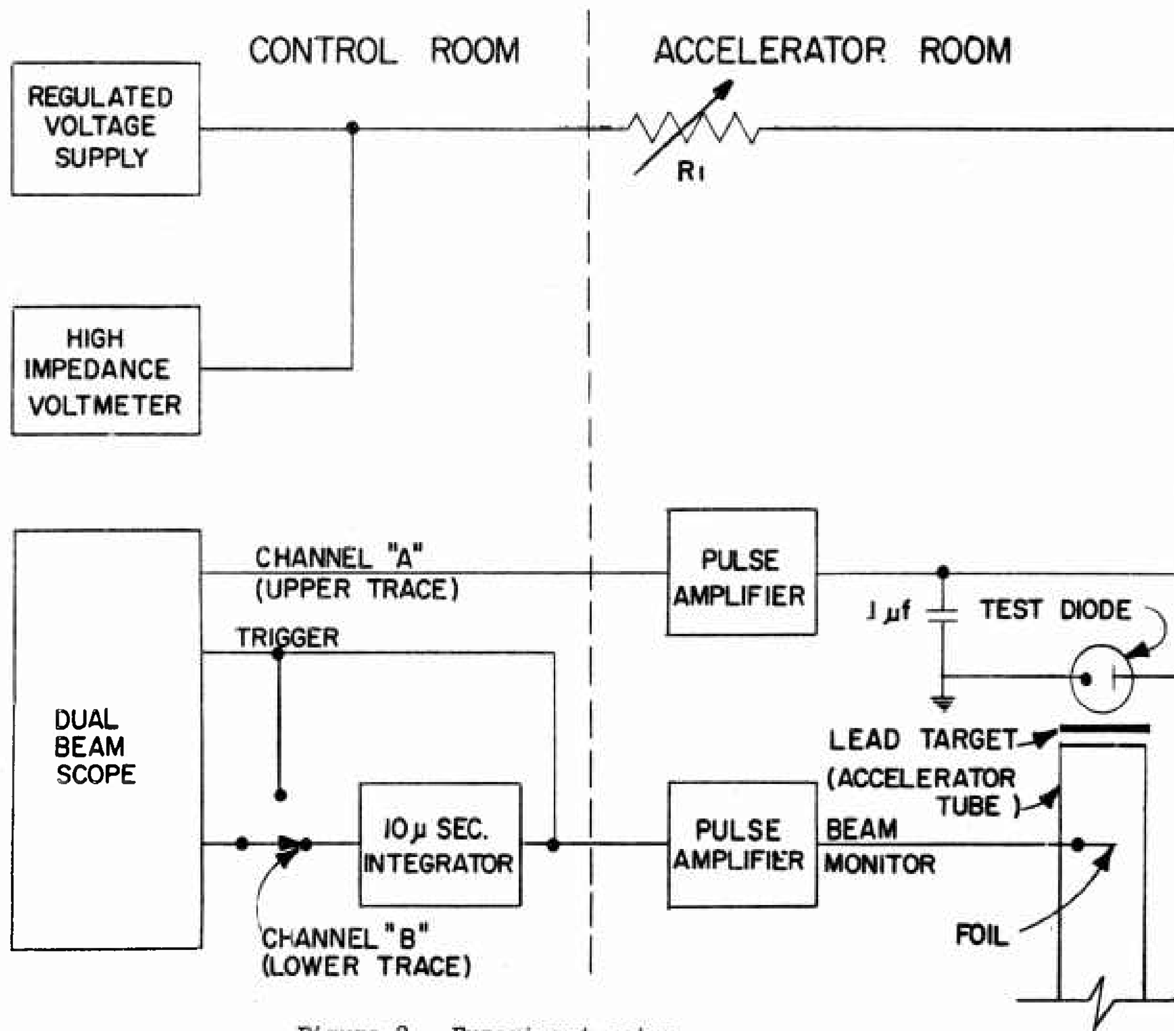

Figure 2. Experiment setup.

Starting at a low value (about 50 percent V_f), bias for the diode being exposed was increased in steps before each gamma pulse until the diode was fired by the succeeding pulse. Then the electron beam current was decreased and the same steps were followed until the diode fired at a lower gamma dose and a higher bias voltage. The above procedure was repeated until diode bias for function was greater than 95 percent V_f.

Measurements were made also of firing time -- time elapsed between gamma pulse onset and diode breakdown -- of one diode of each nominal V_f and of a QF848 gas tetrode. Maximum beam current pulses of 4-μsec duration were used to fire the tubes and the time was measured from gamma pulse onset to diode (or tetrode) breakdown.

Measurements were made to determine gamma dose rate effect on firing time and sensitivity of diodes. The dose-bias firing thresholds were determined for the shortest (0.6 μsec) and the longest (3.4 μsec) gamma pulses obtainable (at that time) with comparable total dose in each case.

Dosimetry was accomplished indirectly by monitoring the electron beam current. The electron beam went through a thin titanium foil within the accelerator tube, producing secondary electrons, which were monitored by means of the circuit shown in figure 2. The gamma dose corresponding to the energy of a given electron pulse was determined by a calorimetric calibration. Using repetitive pulsing, the heating rate of a copper block in the gamma field was measured by means of a thermocouple. The energy received by the copper block was calculated in terms of gamma dose and related to the integrated individual electron pulse and the pulse repetition rate. The beam monitor pulses were observed and photographed in the control room, either directly or integrated (10-μsec RC integrator).

5. RESULTS AND CONCLUSIONS

The dose-bias firing threshold measurements gave data that are plotted in figures 3 through 9. Comparison of these curves shows that for a given percentage bias, the gamma firing sensitivity (or the useful nuclear-proofing range from a nuclear explosion) of a diode is in general greater for diodes of lower V_f. Diodes of all the V_f values tested would be applicable to nuclear proofing and would provide device protection at ranges that can be determined by use of the references as explained below. Ranges may be calculated in terms of gamma dose. In figure 4, a comparison is shown of XD1C dose-bias threshold values from the Plumbbob Tests and those from the linac.

The diode firing time measurements, plotted in figure 10, indicate that the time between the onset of the gamma pulse and diode breakdown is in general inversely proportional to the nominal V_f of the diode and is between 1 and 10 μsec for all the diodes tested. For high-voltage diodes, breakdown occurred before the end of the gamma pulse. Diode breakdown before the end of the gamma pulse was not observed during firing threshold measurements, because in most of these shots deflection of a meter across the diode was taken as the indication of firing. Diode

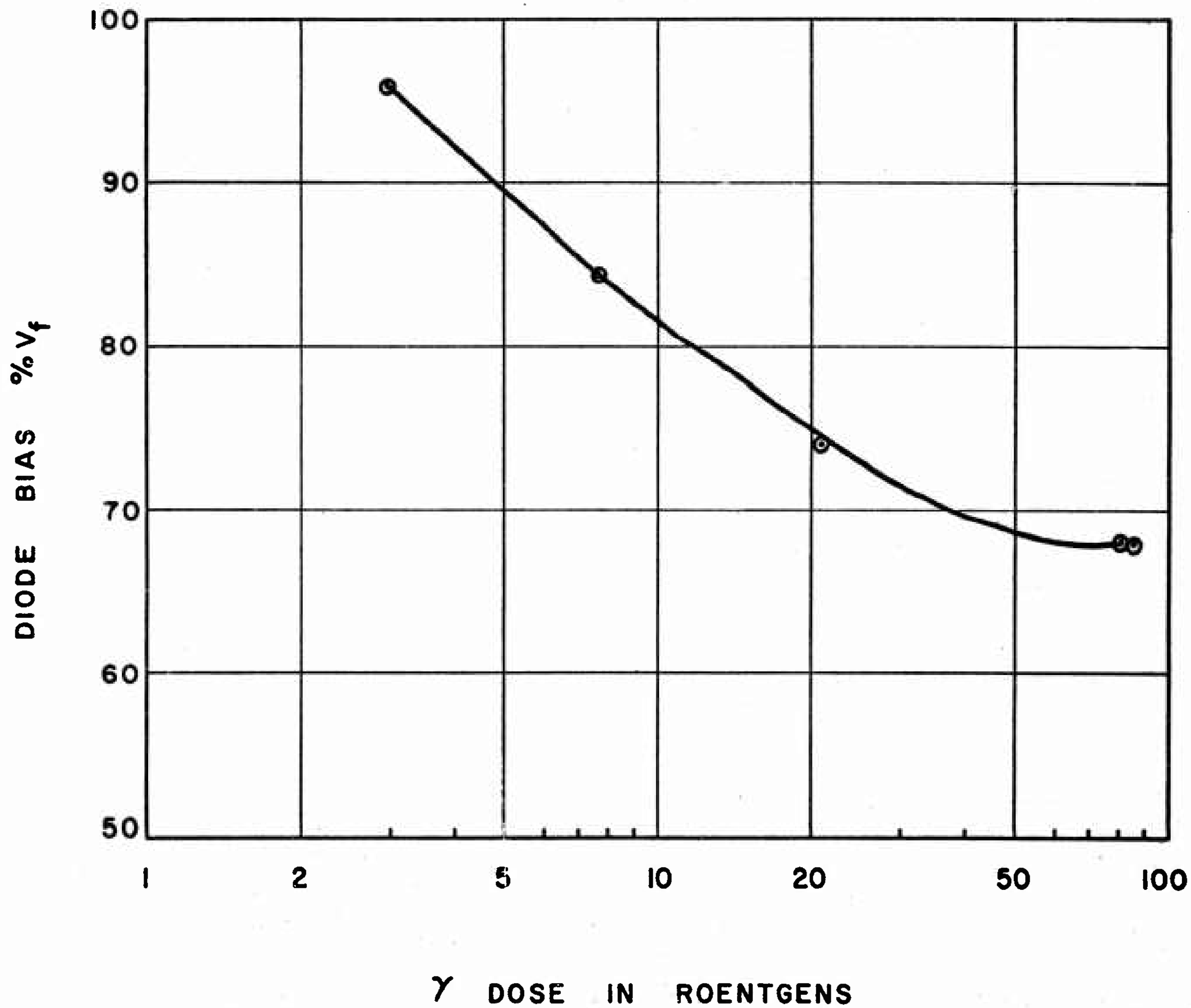

Figure 3. Dose-bias firing threshold for XD-100.

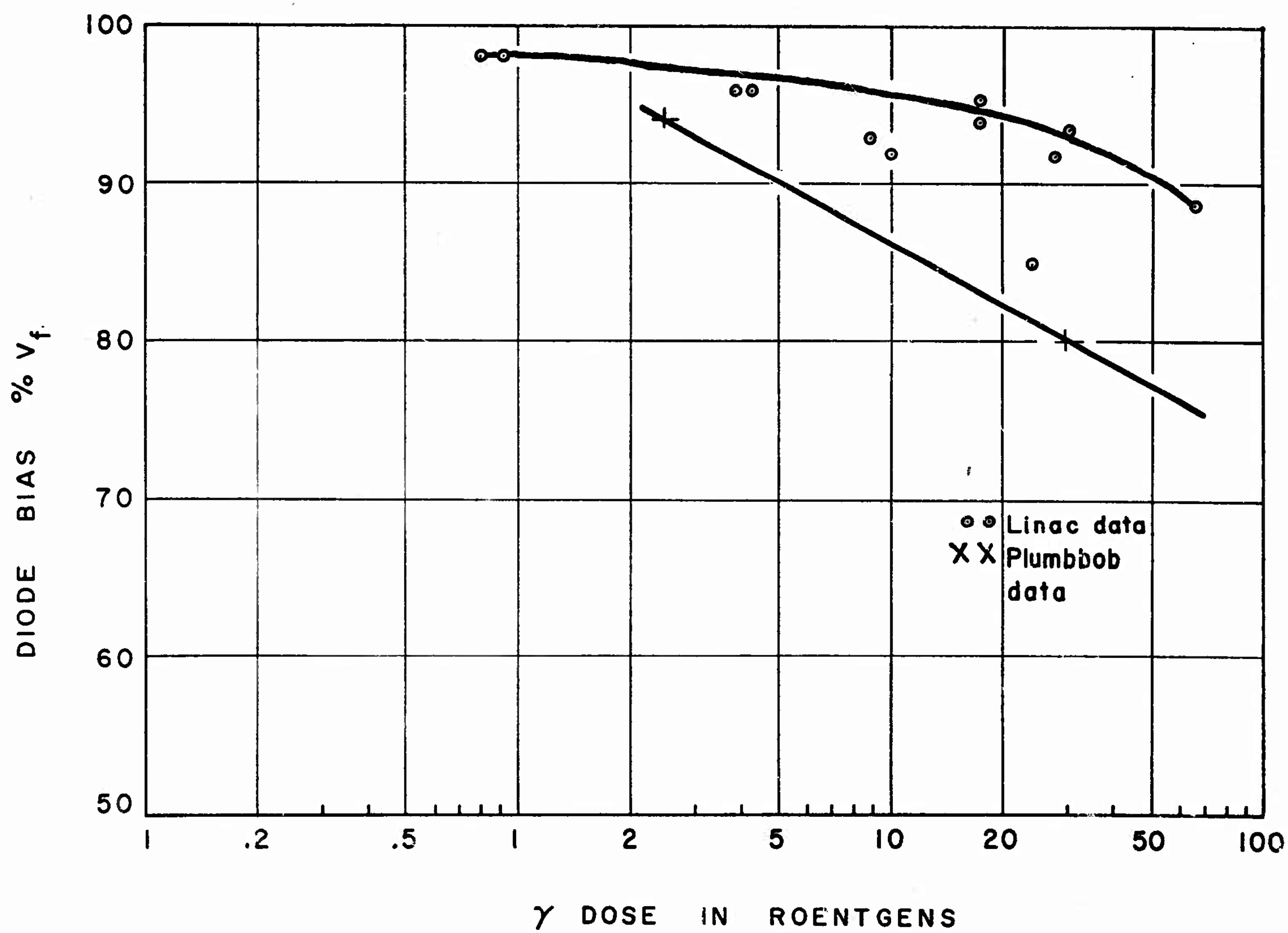

Figure 4. Dose-bias firing threshold for XD1C (113 v) with comparable threshold curve from operation Plumbbob tests.

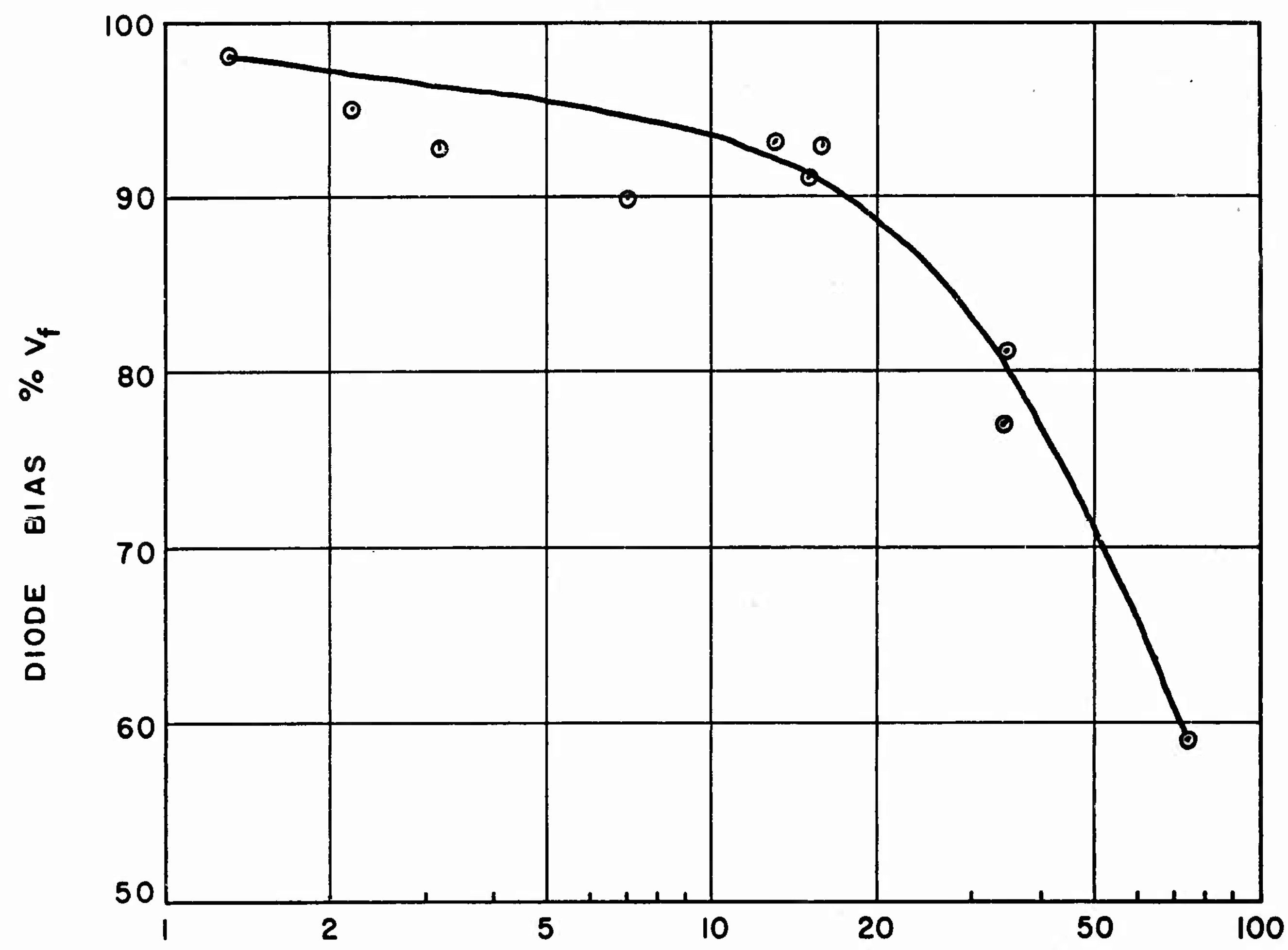

Figure 5. Dose-bias firing threshold for XD-150.

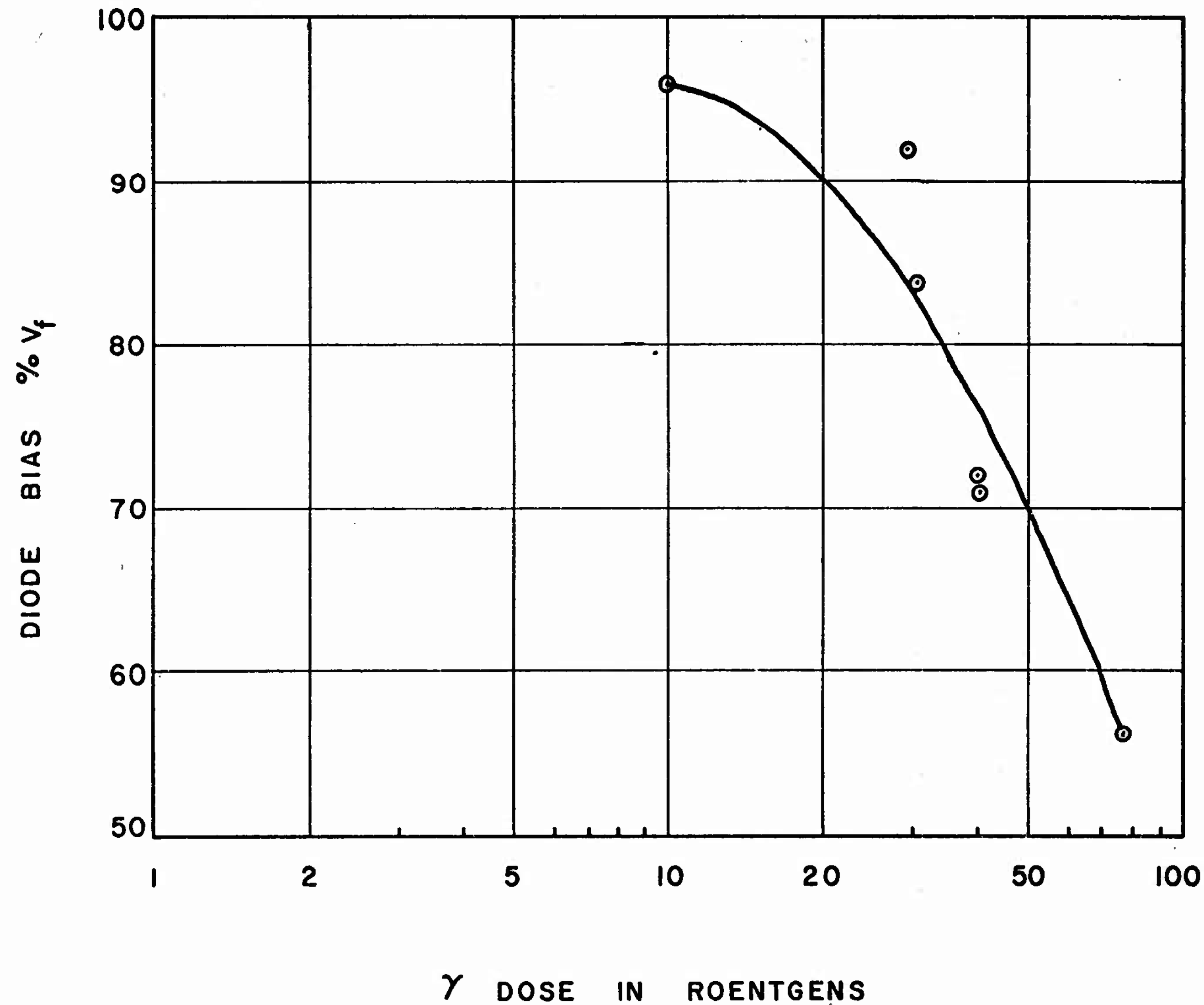

Figure 6. Dose-bias firing threshold for XD-225.

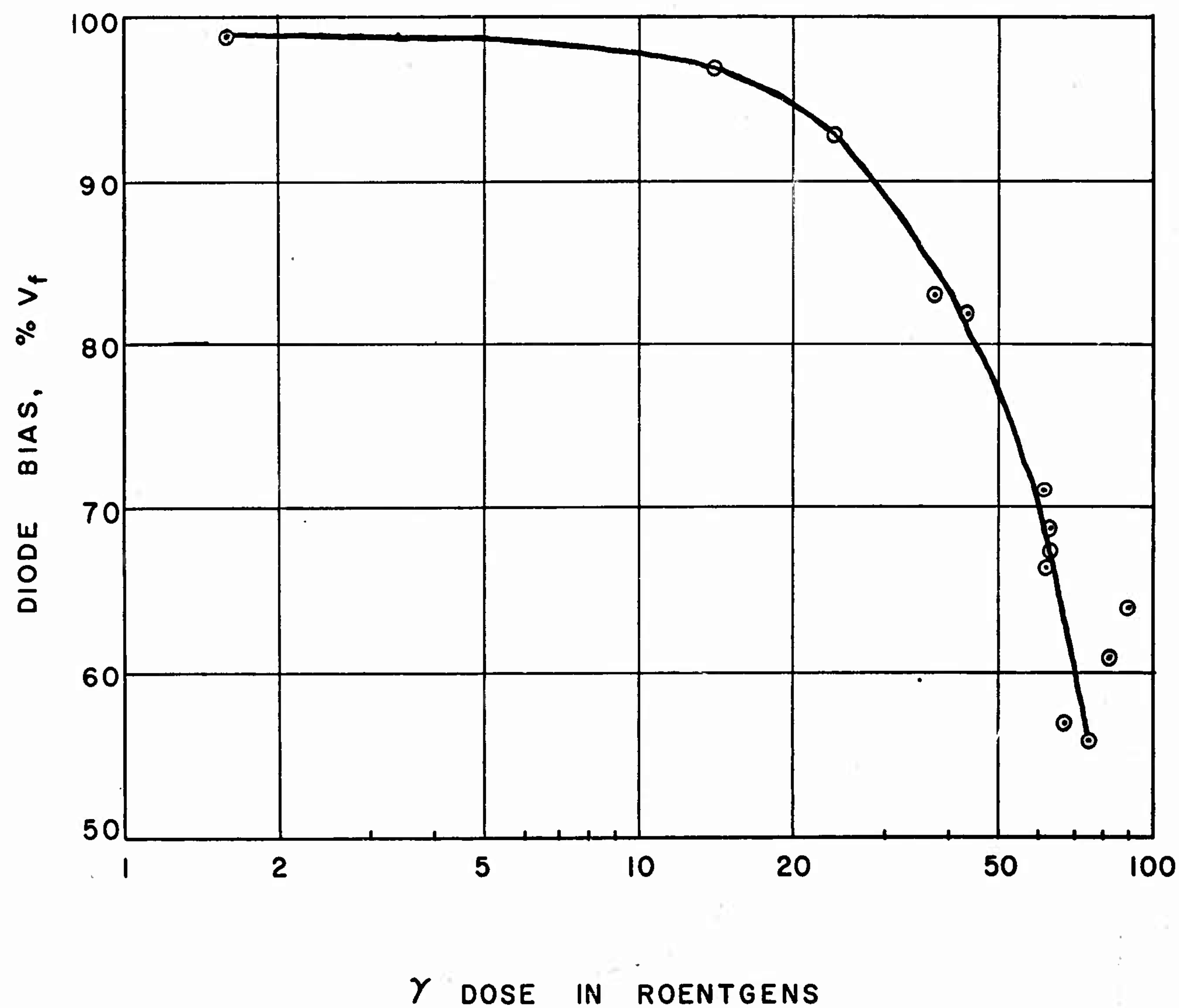

Figure 7. Dose-bias firing threshold for XD-300.

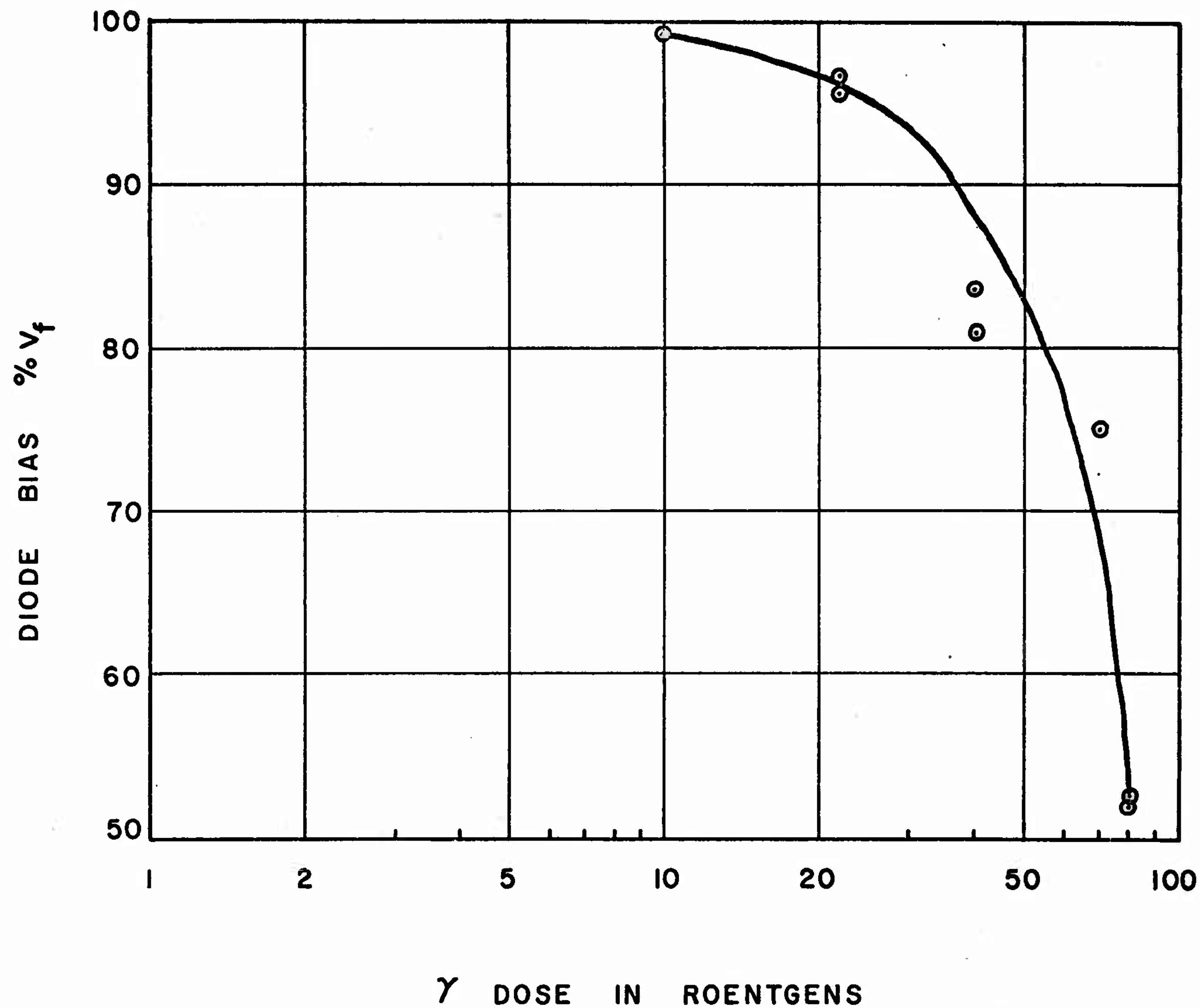

Figure 8. Dose-bias firing threshold for XD-375.

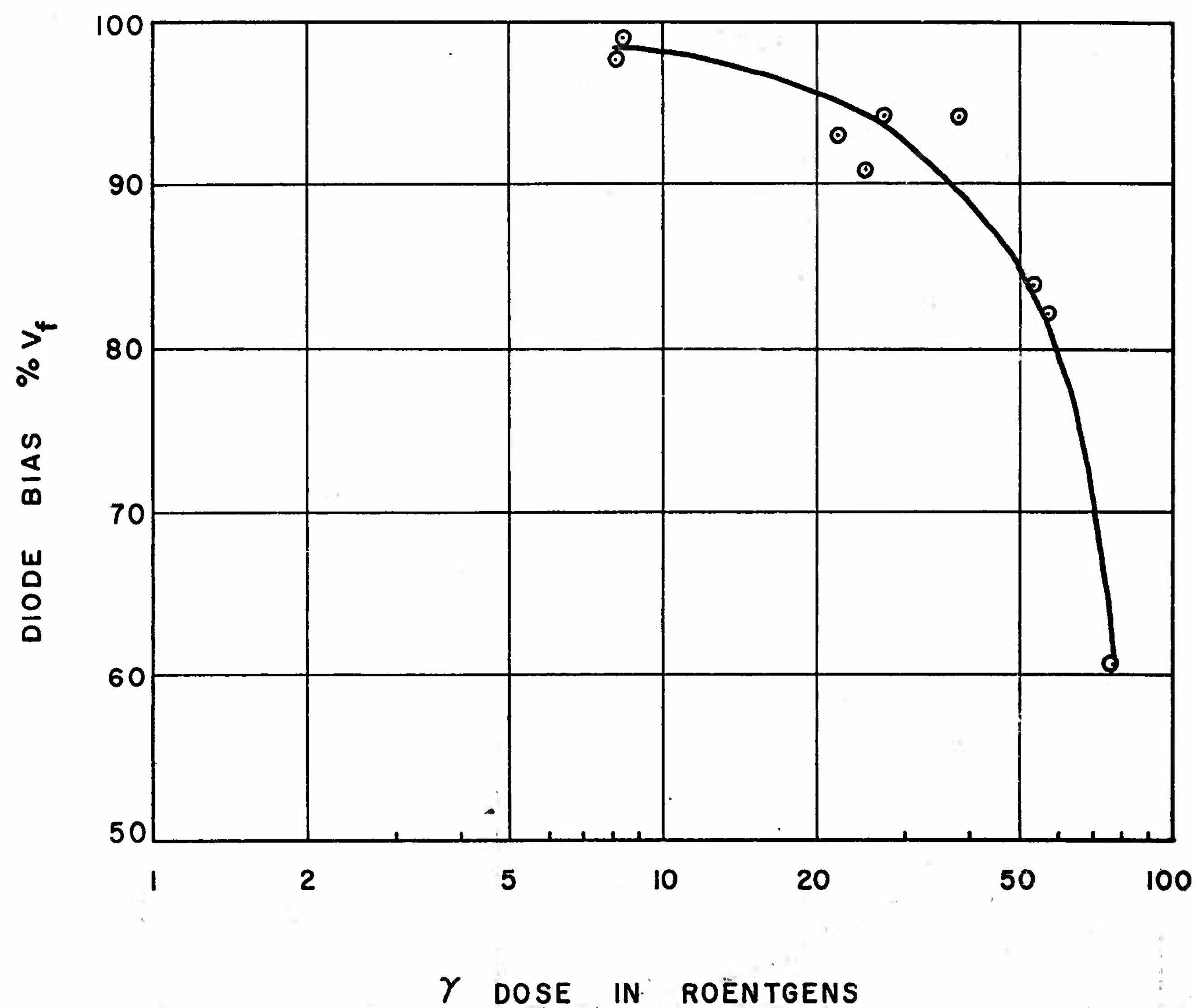

Figure 9. Dose-bias firing threshold for XD-750.

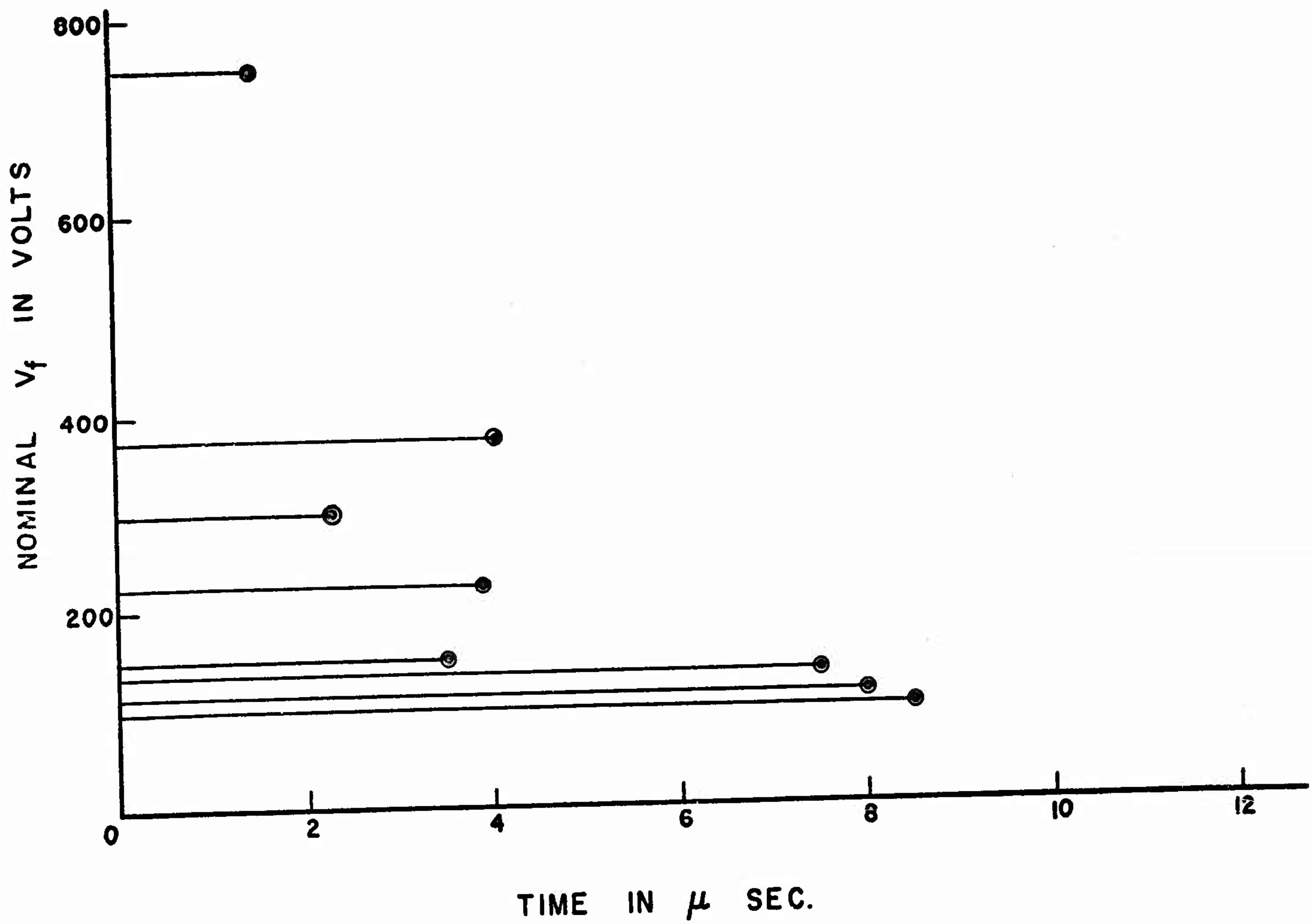

Figure 10. Diode firing time versus nominal V_f.

breakdown was indicated on the scope, but due to the scale settings used, the front of the diode pulse was generally not seen.

Firing time of a QF848 gas tetrode with plate voltage at normal operating value was found to be shorter than that of the lower-voltage diodes. Firing times of diodes and of the components of the circuit being protected would have to be considered in nuclear proofing applications. The QF848, if used in the firing circuit of a fuze, might be fired by a gamma pulse before the protecting diode breaks down.

Figure 11 shows a scaled reproduction of a typical photograph of the linac unintegrated electron pulse (curve A) and the voltage drop of the diode on firing (curve B). Figure 12 shows the integrated electron pulse and the corresponding diode voltage drop on firing.

The data have been presented deliberately in terms of gamma dose rather than dose rate. Dosimetry was limited to providing only the total dose per pulse and the pulse length, and thereby an average dose rate for the pulse. True instantaneous dose rates were not obtainable. The attempt to measure dose rate effects on diode firing yielded questionable results for reasons discussed in section 6. For the Operation Plumbbob diode tests, gamma dose values were obtained from reference 6. Gamma dose rates as a function of range for nuclear explosions can be obtained from formulae and curves in references 7 and 8. (The latter two reports are more difficult to obtain than are the other classified reports referred to.) Diode breakdown as a function of dose rate has been considered on the basis of the rather sketchy dose rate data. The ratio of the Operation Plumbbob and linac gamma dose rate/diode bias threshold values (average rate for first 4 μsec) is about the same as that for gamma dose.

6. LIMITATIONS OF THE EXPERIMENT

The dose rate dependency experiment was unsatisfactory for several reasons. The linac was giving trouble at the time, making adjustment of beam current pulse length difficult and unstable. Consequently, the energies of the long and of the short pulses were not nearly equal as they should have been. Because of time limitation, the dose rate dependency data taken were too meager and scattered to be of any use.

The 7-Mev electrons used to provide the gamma pulses were afterward found to yield effective gamma energy of about 3 Mev; 4- to 5-Mev gammas would have more closely simulated the nuclear weapon gamma spectrum. Linac is more tractable at higher electron energy levels and delivers stabler pulses more easily. For these reasons higher energy should have been used. The nonrepeatability of beam current at low energy and very short pulse lengths practically precludes the possibility of low energy dose rate experiments with the linac.

Although V_f was measured at intervals, a small uncertainty as to percent bias between measurements of V_f during the first few firings for each diode was attributed to the use of unstabilized diodes.

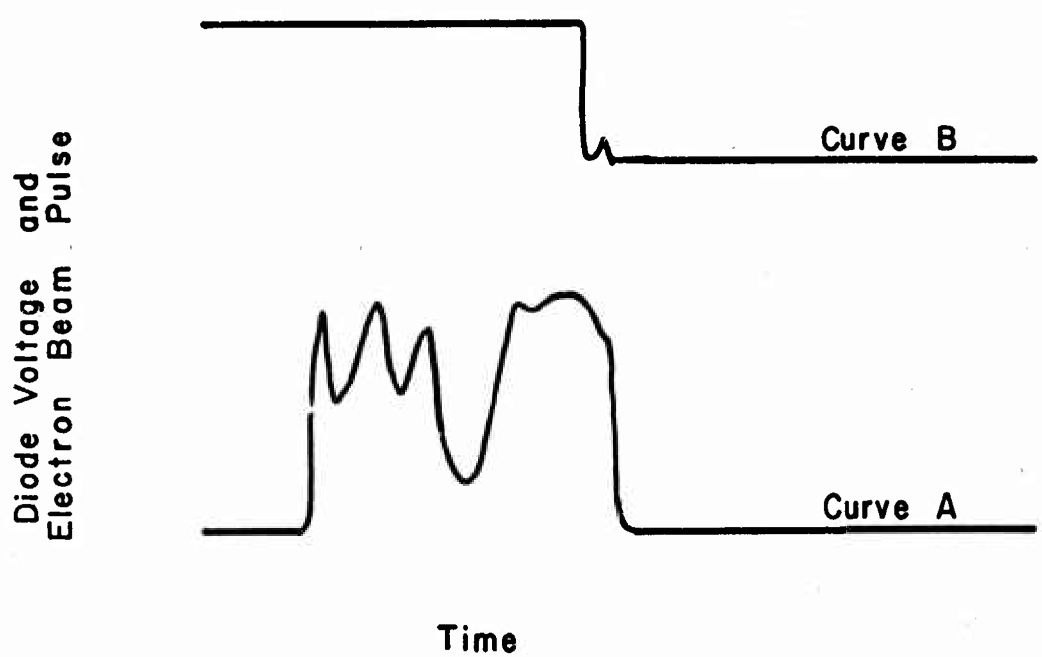

Figure 11. Linac electron pulse and diode firing voltage drop.

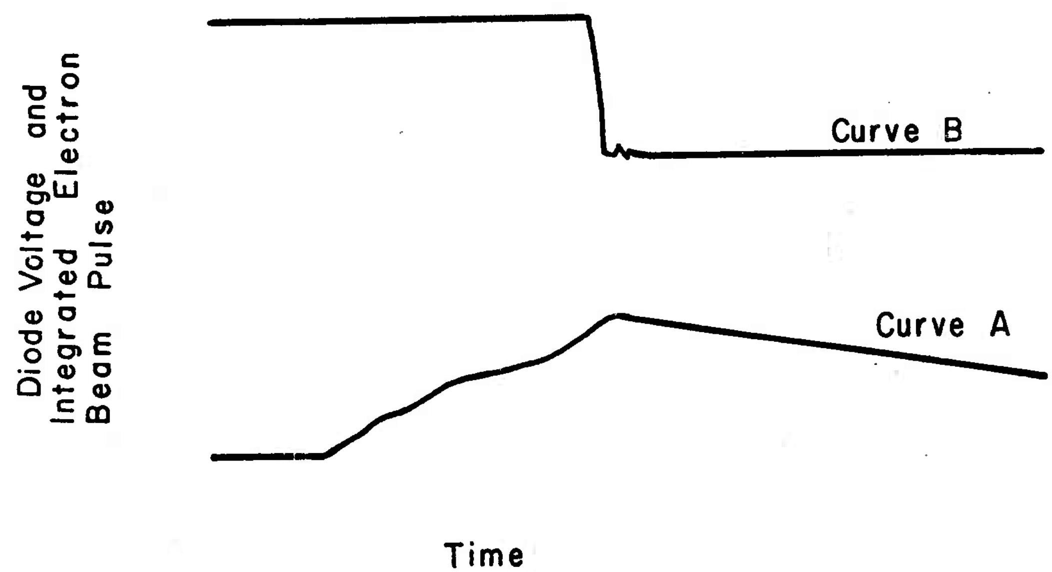

Figure 12. Integrated linac electron pulse and diode firing voltage drop.

The indirect dosimetry used involved the assumption that the heating of the copper block corresponded to the average gamma dose received by the block. Direct gamma dosimetry would be desirable.

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ACKNOWLEDGMENT

The authors wish to express their appreciation to Dr. V. A. J. Van Lint of the General Atomic Division, General Dynamics Corp, for the use of his special equipment and assistance in its application and to Mr. T. E. Foulke of the Lamp Division, General Electric Co, for providing diodes for testing.

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TR-961, 10 July 1961, 6 pp text, 12 illustrations, Department of the Army Proj. 507-06-011, OMS 5530.12.512N, DOFL Proj. 54050 - UNCLASSIFIED Report.

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Gamma actuated switch

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Miniature cold-cathode diodes of the GE XD series were subjected to pulses of gamma radiation from the electron linear-acceleration (linac) facility at General Atomic at La Jolla, California, to determine under laboratory conditions the values of gamma dose and dose rate required to initiate breakdown in the diodes at different bias voltages. Elapsed time between gamma pulse onset and diode breakdown was measured. Curves are presented of the relationship between gamma dose and diode breakdown as a function of diode voltage. The data are compared with similar data taken in Operation Plumbbob (Nevada 1957). The results show that each of the diodes tested is applicable to nuclear-proofing devices with corresponding operating voltage range.

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Diamond Ordnance Fuze Laboratories, Washington 25, D. C.

PULSED GAMMA INITIATION OF BREAKDOWN IN GAS TUBES -- Alan J. Talbert and Neil D. Wilkin

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